CHILLERS SYSTEM OPERATIONS AND MAINTENANCE GUIDE

(Adapted from the Operations and Maintenance Manual for Energy Management by James E. Piper.)

This paper informs you how to keep chiller systems in good shape. These guidelines are general for typical systems and parts that serve normal building or process loads and work in what could be called routine uses. You may need to change these guidelines to fit the maintenance needs of your individual application. If changes need to be made, the equipment vendor is the best place to get more information. Almost every chiller systems manufacturer has put out information about how much maintenance their equipment needs. They will help you make a maintenance plan that is just right for your needs.

For the purposes of this paper, chiller systems are described as a building's main cooling equipment, which includes the central chiller, chilled and condenser water piping, chilled and condenser water pumps, and the cooling tower. We will only talk about how these parts of care affect energy use.

CONSIDERATIONS FOR CHILLER SYSTEM ENERGY MAINTENANCE

Chiller systems cost a lot of money for buildings. It costs a lot to buy, run, repair, and replace them. If they fail, they are just as expensive in terms of time and work loss.

Almost always, the chiller is the biggest energy consumer in the building. When the fans and cooling tower that go with a chiller are taken into account, chiller systems use a lot of power. In order for chiller systems to work well, they need to be well taken care of.

The building's cooling system might be the one that gives the best return on the money spent on maintaining it. Comprehensive chiller system maintenance will extend the life of the equipment, make the system more reliable, use less energy, use less refrigerants, lower the cost of breakdown repair, and cut downtime costs. Rule of thumb: For every dollar you spend on maintenance, you save ten dollars on running costs and repairs.

Since so much depends on keeping the chiller system in good shape, you would think that all chiller systems are well taken care of. Sadly, not many of them are. In real life, you are just as likely to find the attitude "If it isn't broken, don't fix it" as you are to find one that values thorough predictive and preventive maintenance. Even people who think they are doing a good job of maintenance often fail to do many of the things that are needed to keep systems running smoothly. Surveys of sites that looked at the state of chillers and cooling towers show this to be true. In one study of the state of cooling towers, it was found that nearly 70% of the towers had problems that were bad enough to cut the tower's effectiveness by at least 10%. Almost half of the towers couldn't work at more than 80 percent of their design load.

When the capacity of a tower goes down, the temperature of the water that goes back to the chiller goes up. For every degree C that the tower return water temperature goes up, the chiller needs 3-4 percent more energy. For example, a 500-ton chiller system with a condenser water return temperature 2 degrees above design uses between 8 and 9 percent more energy to cool the same amount of air. For a typical electric rate of $0.09 per kWh (including demand), this means an extra cost of $9 per hour, $90 per ten-hour day, $2,070 per month, and $12,420 per six-month air conditioning season. Why aren't these parts and processes well taken care of if they are so important to how much energy a building uses? Some building managers just don't know what happens to chiller systems when they aren't well taken care of. Others may only do a quick check because they don't know how much detail and care is needed. Lack of staff is a big reason for neglect, especially in places where upkeep is done only when something breaks instead of as a way to keep things in good shape. Lastly, there is often a problem with not having enough budget. The organization doesn't make money from chiller systems, so it's hard to justify spending money on them, even when they are "working."

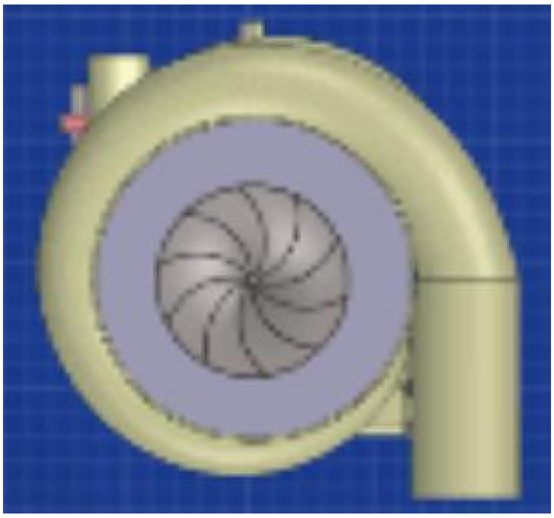
If you want to break out of this pattern, you need to pay attention to chiller systems. You have to show the decision-makers who allocate budget for maintenance how investing to keep chiller system parts in good shape will save both money for maintenance and energy. It is up to you to make a case for maintaining the chiller system.

FOUR TYPES OF BUILDING CHILLERS AND HOW MUCH ENERGY THEY NEED

There are four main kinds of chillers that are used to cool buildings' air: centrifugal, reciprocating, rotating, and absorption. Each one has its own features, pros and cons, and needs for care and upkeep. The amount of energy they use depends on the size and load of the chiller as well as the type of chiller.

Manufacturers of chillers can tell you how much energy their units are designed to use. Energy efficiency is measured in kW of electricity used per ton of cooling made by units that are powered by electricity. The energy efficiency of absorption units is measured in Btu of heat load in per ton of cooling made. In order to compare the real performance of a chiller to the manufacturer's grade, the chiller must be run under the same conditions, which are usually full load, chilled water supply at 7°C, and condenser water temperature at 29°C.

<u>Centrifugal chillers</u>



Centrifugal chillers are machines that use rotating impellers to compress the refrigerant vapor. Inlet vanes limit the flow of refrigerant to the rotor, which changes the amount of cooling that can be done. Most centrifugal chillers used today are powered by electric motors, but they can also be run by natural gas, diesel, or steam turbine engines.

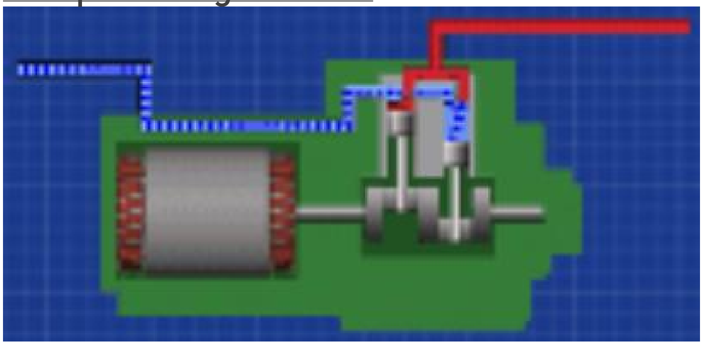
Centrifugal chillers are often used in places that need to cool medium to large amounts of air. They can be used to cool loads with capacities ranging from 90 to 10,000 tons. Most of the units already in place weigh between 150 and 500 tons.

Over the past few years, centrifugal chillers have gotten better at how well they work. When running at full load, the efficiency of new centrifugals was between 0.70 and 0.85 kW/ton ten years ago. Changes to the way chillers are made have made these numbers better, and now most new centrifugal chillers are rated at between 0.50 and 0.60 kW/ton at full load.

One of the biggest problems with centrifugal chillers is their part-load efficiency. When the building's load goes down, the chiller shuts some of its inlet vanes, which slows the flow of refrigerant. The output of the chiller can be controlled well with inlet gear controls, but this comes at the cost of less efficient operation. For example, a chiller with an efficiency value of 0.60 kW/ton at full load might need as much as 0.80 kW/ton at half load and even more at lower cooling loads.

Centrifugal chillers are good because they don't need a lot of upkeep. But it's important to keep them in good shape. If you don't take care of a centrifugal chiller, it won't work well and will break down quickly, needing expensive repairs and a lot of downtime.

Reciprocating Chillers



Reciprocating chillers are positive displacement blowers that use one or more pistons to squeeze a refrigerant gas. Almost all of them are powered by electric motors. In a system with more than one compressor, the cooling capacity is managed by adjusting the flow of refrigerant gas to the compressor and by adding or taking away compressors.

In smaller sites with cooling loads of 100 tons or less, reciprocating compressors are often used. Units are available in sizes from 10 to 200 tons, but because of their size and efficiency, they can only be used for loads of 100 tons or less. Most reciprocating chillers, which are not as efficient as centrifugal chillers, have full-load operating efficiencies in the range of 0.84 to 1.00 kW/ton when they are brand new.

Reciprocating chillers have some advantages. They cost less than other types of chillers for units with 100 tons or less. They work at a higher condensation temperature, which makes them a good choice for situations where air-cooled condensers are needed. Installing multiple units makes it easy to meet different cooling needs. When operators use more than one unit, they can also set up their process for partial loads without losing efficiency.

There are two major problems with how they are used: upkeep and noise. Reciprocating chillers need more maintenance than other types of chillers, and when they are running, they make more noise and vibration than other kinds of chillers.

Rotary chillers

Rotary chillers are positive displacement compressors with two polished rotors that compress refrigerant gas between their lobes. All are powered by electric motors. Controlling the flow of refrigerant gas to the compressor changes how much cooling can be done.

Rotary chillers are only used in places where other types of chillers, especially centrifugal chillers, can't be put in because of their size or weight. Units come in sizes ranging from 20 tons to 2,000 tons, but most uses fall between 175 tons and 750 tons. Their full-load efficiencies run from 0.70 to 0.80 kW/ton, making them more efficient than reciprocating chillers but less efficient than centrifugal chillers.

Even though rotating chillers require a high initial investment, they have a lot of benefits. Because they are small and relatively light, they can be put in places where other types of chillers couldn't fit. Their few moving parts mean that they need less upkeep and run more quietly and with less vibration.

Screw chillers

Screw Chillers are vapor compressor chillers that move the water through the system with the help of a screw compressor. Some of the most important benefits are small installation, quiet operation, lower costs for upkeep, and high energy efficiency. They are also a good choice for tall buildings.

Absorption chillers

Absorption chillers are different from other types of chillers because they get their power from heat instead of from a motor. Absorption chillers can be either directly or indirectly lit. Direct-fired absorbers use natural gas or a similar fuel to make the heat that the unit needs to run. Indirectly fired absorbers get their energy from low-pressure steam, hot water, or waste heat. Water and ammonia are the most popular types of coolants.

Absorption chillers can hold anywhere from 100 to 5,000 tons, but most of them hold between 300 and 500 tons. The amount of heat that these units take in per ton-hour of cooling they make ranges from 11,000 to 19,000 Btu.

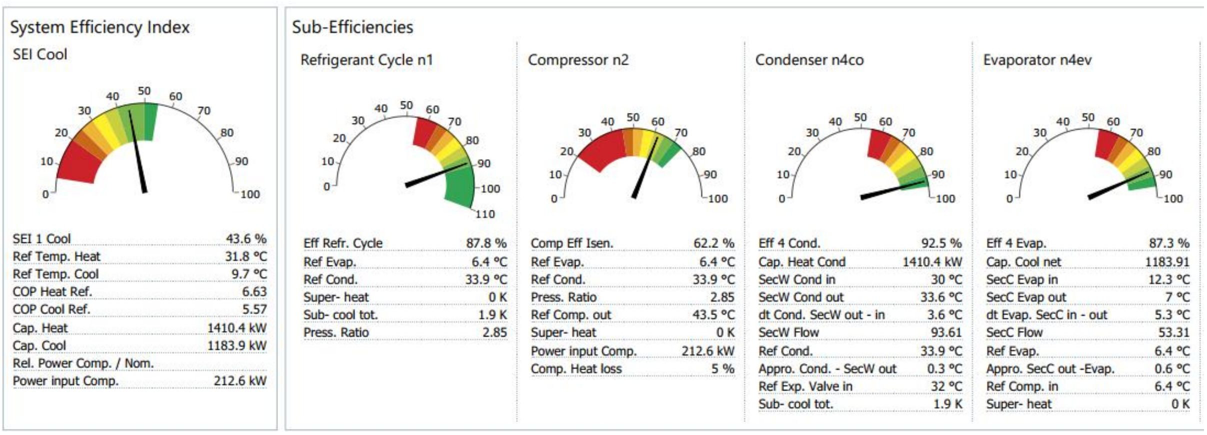
Even though absorption chillers are less thermally efficient than centrifugal chillers, they are often used as an alternative, especially in places where electricity demand charges are high or where there is not enough electricity to run a chiller that is powered by electricity. Indirect-fired absorbers also have the benefit of being able to be driven by a wide range of heat sources, such as low-pressure steam, hot water, solar energy, and waste heat. Absorbers work especially well in places where there is a ready source of waste heat that needs to be gotten rid of.

The main problems with absorption chillers are that they are expensive to buy and require a lot of upkeep. The most common absorbent is lithium bromide, which is a salt. In the presence of oxygen, lithium bromide is very corrosive to steel, so corrosion inhibitors must be used to protect the units and they must be kept closed.

HOW TO KEEP BUILDING CHILLERS IN GOOD WORKING ORDER TO SAVE ENERGY

A thorough scheduled maintenance program is the best way to improve the performance, dependability, and life of building chillers. Programs work best when they are made for a specific purpose and strike a balance between the amount of maintenance work needed and the desired level of reliability and chiller efficiency. Even though the programs are different, they all have three things in common: maintenance logs, scheduled inspections, and scheduled maintenance tasks.

The repair log is one of the best ways to take care of a chiller. By regularly logging and analyzing data, operators can keep track of how well the chiller is working. When the chiller is working well, it is important to keep track of the data so that you can compare it to the data when problems arise. The logs show operating engineers and repair staff how the chiller has been used in the past. Reviewing the data will help find trends in how well the chillers work—trends that happen slowly enough that they don't show up in day-to-day operations. For the logs to be useful, they must be filled out every day and looked over often. With the microprocessor-based control panels , it's easy to get the data because the necessary data is instantly collected and saved in a file for later use. Alternatively, consider installing a chiller monitoring system.



Data obtained by an advanced chiller monitoring system make manual logging obsolete and will flag performance drift and maintenance issues

Most chillers are inspected daily, weekly, monthly, and once a year on a set schedule. At least once per shift, the operation of chillers is checked at some large chiller plants. The reason why checks are done so often is to find small problems before they turn into big ones that slow down performance or cost a lot to fix. Many of the checks can be done while the chiller is running, and they only take a few minutes. For other inspections, the chiller needs to be turned off and, in some cases, partly disassembled.

Scheduled maintenance activities also are conducted on a daily, weekly, monthly, and annual basis. Every two or three years, depending on the state of the chiller and the environment in which it works, other activities may need to be done. Like planned inspections, scheduled maintenance is meant to keep things in good shape.

Before making a plan for chiller inspection and maintenance, it is important to know what factors affect chiller operation and what can be done to control them. **Fouling, corrosion, and scale are the three biggest things that negatively affect the performance of the chiller.** Energy managers need to keep a close eye on all three of these things because each one can make a chiller run less efficiently. With regular inspections and repair, you can easily keep an eye on all of these things.

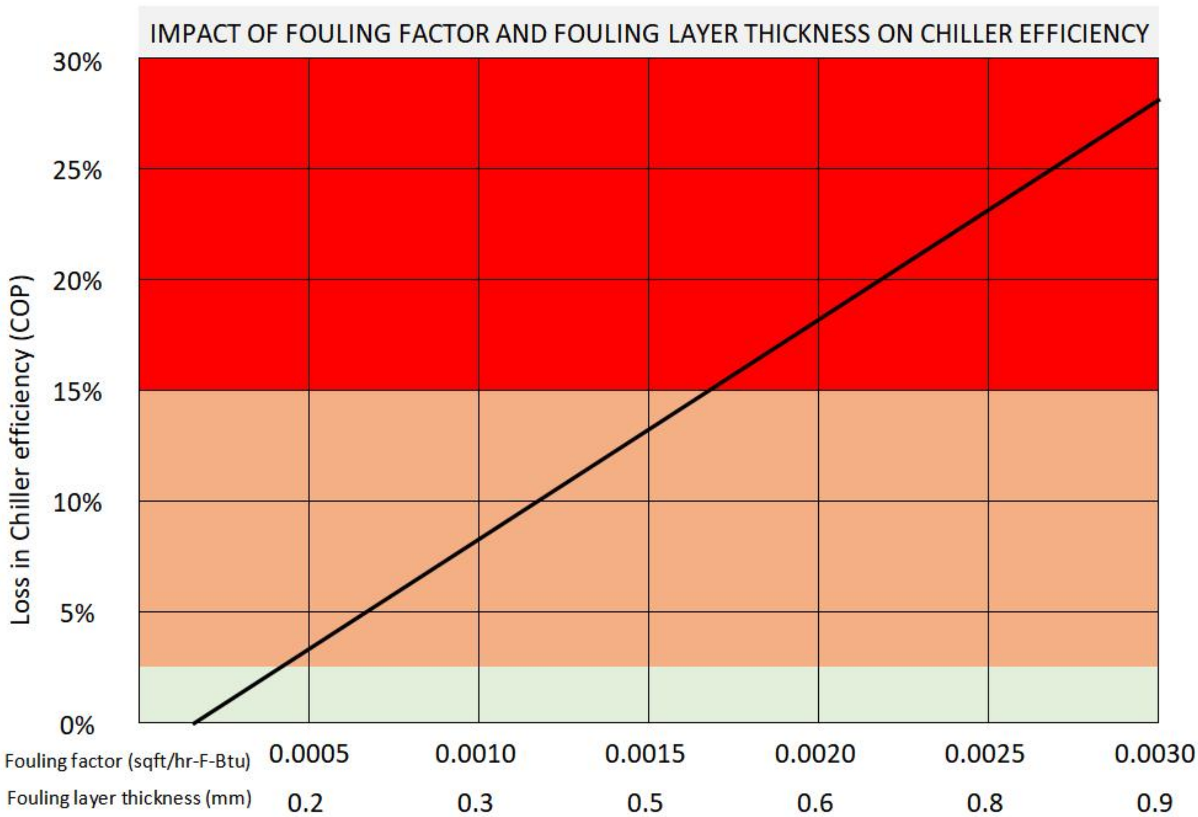
How fouling occurs in chillers

Fouling happens when solids in the water that flows through the chiller fall out of suspension and slowly build up on the heat transfer surfaces. As the solids build up on the surfaces, they make it harder for the heat to move from the refrigerant to the cold and condenser water that moves through the system. Scale also keeps corrosion inhibitors that are added to the water from getting to the metal of the heat-exchangers. If fouling isn't addressed, it will lower the chiller's operating capacity, make it take more energy to reach a certain level of cooling, put more stress on the chiller's parts because of the higher operating temperatures, and cause a lot of corrosion damage or block the passages in the chiller's heat-exchangers. Unfortunately, fouling is usually not noticed unless the working conditions are closely watched or the chiller runs at full load for a long time. Because its effects are so hard to see, many maintenance workers don't recognize that fouling is a big problem.

But fouling is a big problem, especially when it comes to how well a chiller works. Even a small amount of buildup on surfaces increases the resistance to heat transfer within the chiller. The fouling factor measures how hard it is for heat to transfer through a chiller. When the fouling factor is high, it makes it harder for heat to move, which makes the chiller less effective. When a chiller is new and its heat transfer surfaces are clean, its fouling factor is usually 0.0002 or less. Most vendors say that if the fouling factor goes above 0.005, you should fix it.

Even with good care and a thorough water treatment program, the fouling factor will rise to about 0.001 after one year of operation. This means that the chiller will run with higher condenser temperatures and pressures. It will go up even more if there isn't good upkeep and a full water treatment program.

There are often chillers that look like they are working well but have a fouling factor of 0.0025 or higher. With a fouling factor of 0.0025, heat transfer is slowed down enough to cause condensation temperatures to rise by 2.2–2.8°C and condensation pressure to rise by 5-8 psi (35–55 KPa). This means that to keep the same level of cooling, the fan will need about 25% more energy to do the same job. The graph below shows the relationship between chiller fouling factor and chiller efficiency.



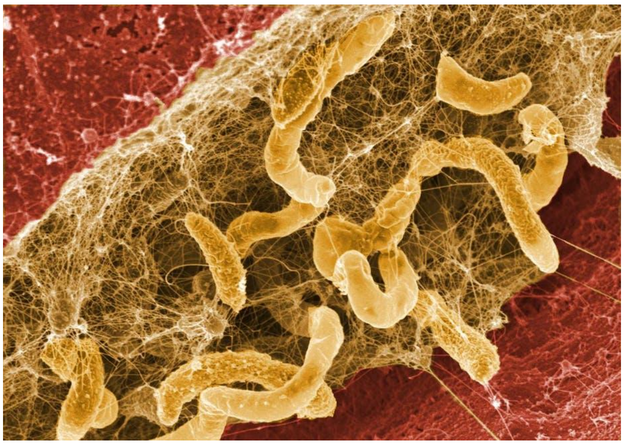
There are three sources for the solids that cause fouling:

- solids contained in the water used by the system,
- solids introduced by the system itself,
- and solids introduced into the system by the cooling tower.

All water contains at least some level of insoluble substances. As water leaves the system through evaporation and blow-down at the cooling tower, these solids become more concentrated in the condenser water system. When make-up water is used to replace the water lost through the tower, it brings in more solids.

Solids that cause fouling can also come from the system itself. Metallic corrosion of pipes and erosion of surfaces let solids into the water system, where they stay in suspension until a chemical reaction makes them settle out, usually on surfaces that transfer heat.

The cooling tower is the third and by far the biggest source of solids that cause fouling. The air is scrubbed by cooling towers. Microscopic organisms and small particles, like leaves, dust, and silt, are taken out of the air by the tower's action and go into the condenser water system.



When large and microorganisms get into the condenser water system, the heat-exchanger of the chiller becomes fouled with biological matter. Large organisms like weeds and floating debris can easily block the tubes of chillers if they are not removed. Algae, fungi, and bacteria, which are all microscopic organisms, grow in the condenser water system and make slime. This slime hinder water flow through chiller tubes and speed up corrosion on metal surfaces. For example, a layer of slime only 0.3 mm on a chiller's condenser tubes raises the fouling factor by nearly 0.001 and causes the chiller to use about 10% more energy to produce the same amount of cooling.

How to Reduce Fouling

Controlling fouling in chillers is easy to do by using a mix of operating and repair practices. One thing that can be done is to make sure that the flow rates of water in chiller systems are within the ranges that the chiller maker specifies. Fouling rates go up when flow rates through chiller heat-exchangers slow down, especially in places where water speed drops off quickly. Keeping the flow rates of condenser and cold water within the recommended range will make it less likely that chiller tubes and end plates will get dirty.

By putting screens on the cooling tower sumps, the number of big particles that get into the condenser water system will go down. If screens are put in, they will need to be checked regularly to make sure that debris doesn't build up and stop or slow the flow of water from the tower to the chiller.

The best way to stop all kinds of fouling in a chiller system is with a thorough water treatment program. Water treatment helps control problems like scale buildup, corrosion, and foaming. It also helps keep the system from getting clogged up.

For the program to work, it must be made to fit the problems in the system that needs to be fixed. Samples of water must be taken and studied to find out what problems are in the water system and how serious they are. Based on the results of the research, a program is made that suggests treatments, amounts, and dosing methods. Once the program is up and running, it must be tested on a regular basis to see how well it is working and to figure out what changes need to be made to protect the water system. When the water supply state changes often, facilities may need to test more often.

Most organizations hire 3rd party water treatment companies to do all or part of the program. These companies do a survey of the existing system and water conditions, make recommendations for specific water treatments based on what they find, give operators guidelines for how to use water treatment chemicals, train in-house staff on how to test water, look over regular water tests, and suggest changes to the chemical treatment program as needed.

Even with a good water treatment plan, some of the moving condenser water will need to be bled off and replaced with fresh water. Because of how cooling towers work, some of the water that flows through the system is always lost to the air through evaporation and mixing with the air that flows through the tower. A tower that is well taken care of and working well will usually lose about 0.2% of the water that flows through it.

Most of the pollutants that would usually be floating in the water are left behind when this water is lost. As a result, there are more solids in the water that flows through the system. Chemically treating the water will help keep these solids in solution for a while, but eventually the concentration of solids will be too high and they will settle out of the water and form scale on the surfaces that transfer heat. Because of this, while the system is running, some of the water that is flowing is always drained from the condenser water system.

How fast bleed-off happens depends on the quality of the water in the system and how fast solids are put into the system. If the rate is too low, the solids will build up in the system. If the rate is too high, it will cost more to treat the water and chemicals. The chemical water treatment company can figure out the best rate of bleed-off as part of their research.

By checking the chiller logs and keeping an eye on the quality of the water in the condenser and chilled water systems, you can see how well fouling is being managed.

Also, the chiller should be opened and checked once a year or twice a year, depending on application and its size. The review will point out if the water treatment program needs to be changed, how fast water is being lost from the system, and what changes need to be made in the chiller operations.

How corrosion happens in chiller systems

Corrosion is an electrical process that breaks down metals in chiller systems. Corrosion affects almost every type of metal used in the devices, such as steel, copper alloys, aluminum, and zinc. Corrosion makes it harder for heat transfer surfaces to do their job, and if it's not stopped, it can destroy the equipment. The amount of microorganisms in the system, the amount of oxygen in the water, the water's alkalinity or acidity, the water's temperature and speed, the amount of dissolved and suspended solids, and the concentration of dissolved and suspended solids all affect the rate of corrosion in the system.

Corrosion can damage the metals in a chiller system in three ways: in a general way, in a local way, or in a galvanic way. All metal objects that come into contact with the water in the system are being corroded. It happens pretty slowly and is spread out pretty evenly throughout the system. Generalized corrosion is a big problem for the efficiency of a system because it makes a lot of oxides that stick to heat transfer surfaces and make the system less efficient.

Generalized corrosion is more about how well the equipment works, while localized corrosion is more about how long it will last. Localized corrosion happens when corrosion happens in small areas of the metals used in the device. Other metal surfaces are usually covered, so all of the corrosion happens in a few small spots. This concentrated movement causes the metal to get holes and pits quickly. Localized corrosion is the worst kind of corrosion, and it is harder to fix and costs more than other kinds. Most chiller tubes are less than 2.5 mm thick, so localized corrosion can quickly eat through and destroy them, letting water and refrigerant mix in the system.

Galvanic corrosion is the third type of corrosion that can happen in chiller systems. Galvanic corrosion happens when two different kinds of metal touch each other directly. When the water is moving, the different metals work like a battery and set up a current between them, which quickly eats away at one of the surfaces. How fast something corrodes depends on the contamination level of the water.

How stop corrosion?

To stop corrosion, you need to know what metals are used in a chiller system and how likely they are to corrode in the working conditions of the system. The best defense is a full water treatment program that takes care of corrosion in the chiller system by making the contaminants in the water less reactive and cleaning hot metal surfaces by putting a protective film on them. Internal corrosion can be kept to a minimum by adding the right mix of chemicals in the right amounts. As with any treatment program, water tests will need to be taken on a regular basis to check on how well the program is working. Also, the chiller tubes should be checked for corrosion once a year or twice a year. Even though galvanic corrosion can be sped up by bad water treatment and lack of chiller upkeep, its rate is mostly determined by how the chiller is made.

How scaling works in chiller systems

Scale is a type of fouling that can happen in chillers. It happens when soluble salts in the water crystallize and stick to heat transfer surfaces, especially on the condenser water side of a chiller. This is bad for how well the chiller works. As water from the tower goes through the chiller, it gets warmer. This makes the water less able to keep suspended minerals like calcium sulfate, calcium phosphate, and calcium carbonate in suspension. The salts then make a hard layer that sticks well to surfaces that spread heat. Scale is basically a specialized form of fouling that is very hard to get rid of. Heat transfer surfaces must be cleaned either with chemicals or by hand. Scale makes a chiller less efficient because it makes it harder for heat to move between the refrigerant and the cooling water. It also makes maintenance more expensive because the chiller needs to be turned off and cleaned from time to time.

How to reduce Scaling?

Scale forms because of three things: the rise in temperature in the condenser of the chiller, the acidity or alkalinity of the water, and the amount of calcium hardness in the water. Good operating and maintenance methods can be used to control all three. By making sure the right amount of water flows through the condenser, the temperature rise in the chiller can be kept to the level suggested by the manufacturer. With a good water cleaning program, you can control whether the water is too acidic or too alkaline. The level of calcium hardness in the water can be managed by treating the water and letting water out of the system in the right way. This will reduce the amount of salts in the water that come from tower water losses.

Address all the above mentioned problems with one single solution?
Automatic condenser tube cleaning solves the big problems listed above (fouling, corrosion, and scaling) and keeps the condenser working well and extends the life of the tubes, which in turn extends the life of the whole chiller.

Automatic Tube Brushing is a proven and effective strategy to prevent fouling and scaling of condenser tubes.

HOW TO SET UP CHILLER MAINTENANCE SCHEDULE

In addition to controlling fouling, scale, and corrosion, there are many other parts of a chiller's operation that need regular and ongoing maintenance for the unit to work well and quickly. The manufacturer of the chiller is the best person to talk to about what jobs need to be done and how often. He knows the most about the equipment and the installation. This part gives you a general idea of how to set up a maintenance plan for chillers. For it to work best, it will need to be adopted to fit the needs of the program.

Most upkeep tasks for chillers are done every day, every week, every month, or every year. See the table below for the tasks an recommended frequency. Depending on the importance of the process that the chiller supports, it may be necessary to do these things more often.

Check and maintenance schedule for electric chillers

Activity	Frequency
Check chiller log	Daily
Check general operating conditions	Daily
Check for irregular noise and vibrations	Daily
Inspect for oil leaks	Daily
Inspect for water leaks	Daily
Check refrigerant level	Daily
Inspect purge unit operation	Daily
Log purge unit counter reading	Weekly
Sample condenser water	Weekly
Inspect water treatment system	Weekly
Inspect valves for leaks	Weekly
Check filters and strainers	Weekly
Check pH of chilled water and condenser water	Weekly
Inspect V-belts for wear and fit	Weekly
Inspect drive couplings for wear	Weekly
Inspect sheaves for wear	Weekly
Sample oil for testing	Yearly
Change compressor oil and filter	Yearly
Sample refrigerant for testing	Yearly
Change refrigerant filter	Yearly
Test purge unit operation	Yearly
Calibrate controls	Yearly
Test linkages for tightness	Yearly
Test safeties	Yearly
Chilled water low temperature	Yearly
Chilled water flow	Yearly
Condenser water flow	Yearly
Refrigerant low/high pressure	Yearly
Low oil pressure	Yearly
Meg motor windings	Yearly
Check motor to compressor alignment	Yearly
Inspect motor mounts and bolts	Yearly
Inspect chiller tubes for scaling and fouling	Yearly
Inspect case for rust	Yearly
Eddy current test tubes	Yearly

Leaking Chillers

One of the most important parts of chiller repair is making sure the system is in good shape. In devices with a lot of pressure, refrigerant will leak out into the air. In low-pressure systems, air and moisture can be drawn into the chiller's refrigerant system.

In both systems, water can get into the refrigerant system if there are leaks between the refrigerant and the condenser or cold water systems. By finding and fixing leaks, the facility will be able to meet clean air laws, use less refrigerants, make the chillers run more efficiently, and reduce the wear and tear on chiller parts.

The biggest worry with low-pressure chillers is that air and moisture will get into the refrigerant system. Air is a noncondensable gas that makes the chiller much less efficient. Moisture makes it hard for the refrigerant system to work, and it can also turn into acids that damage quickly the bearings, gears, and motor windings in completely sealed chillers.

Low-pressure chillers should be checked for leaks all the time. By keeping track of the system's working pressures and the surrounding conditions, operators can find changes in how the system works that are caused by air in the refrigerant. Also, samples of the coolant should be taken at least once a year and sent to a lab for testing.

All low-pressure chillers should come with purge units that work well. The purge unit's job is to get rid of any gases in the refrigerant that can't be cooled down. Even though all purge units lose some refrigerant when they work, losses are much smaller in high-efficiency units. A run-time monitor or a simple frequency counter can be used to keep an eye on the working of a purge unit in order to find leaks. By keeping an eye on how the purge unit works, operators will be able to find leaks as soon as they happen.

Loss of refrigerant is another kind of leak that can happen with high-pressure chillers. This makes the chiller less efficient, which means it needs more energy to run.

Testing of the Tubes

The heat-exchanger tubes are one of the most common places where chillers leak and also one of the most expensive parts to fix. Leaks in the tubes happen slowly. Corrosion, erosion, pitting, and thermal stress are the main causes. If the broken tube is found early, it can be fixed or changed before it starts to leak. At least once every two years, the heat-exchangers in chillers should be taken offline and opened so the tubes can be checked. Every year, you need to test big chillers, older chillers, and chillers that are used for important tasks. Visual analysis can find problems like heavy fouling and corrosion, but it can't find most of the things that cause leaks. An eddy current tester is used to find problems as they are starting to happen.

Eddy current testers use an alternating current to create a magnetic field around a probe that is put into the heat-exchanger tubes. As the probe moves through the tube, it causes an eddy current in the tube. Changes in the eddy current are caused by flaws in the tube, such as corrosion, pitting, and thinning. By watching how the current changes, an experienced user can figure out where and how big the problem is in the tube. If the problems found are big enough, they can be fixed while the chiller is turned off.

Tests with eddy currents should be compared to tests that have already been done. By keeping track of the test results, you can see how the heat-exchanger tubes are doing over time. This lets you know how quickly the tubes are breaking down and how soon they will need to be fixed.

Testing the refrigerant
The system can't work right or last as long as it should if the refrigerant isn't in good shape. Even with normal use, moisture, corrosion, and other things can get into the refrigerant and make it less effective. These contaminants can cause sludge to build up at the bottom of the evaporator shell, acids to form that eat away at the metal surfaces inside the chiller, and heat transfer surfaces to break down.

It is recommended to sample the refrigerant and send to a qualified lab for testing at least once a year. The refrigerant sample gives a very clear picture of how the insides of the chiller system are doing, so problems that could cause damage can be found before they lead to a major system makeover.

Testing the Oil
Like refrigerant testing, oil testing tells you about the state of the chiller's internal parts. Rule of thumb: An oil sample should be taken and sent to a trained lab for analysis at least once a year. The test results will show how much contamination is in the compressor oil. For example, if there are metal bits in the oil, it means that parts like bearings and gears are wearing out. The results of oil samples should be registered and kept track of over time. When the amounts of certain contaminants rise, it's a sign that the chiller is starting to wear out.

Important notes for maintenance on an absorption chiller:
Many of the maintenance tasks for absorption chillers are the same as those for vapor compression chillers. See the table below. As with care for vapor compression chillers, these tasks are the bare minimum that should be done to keep these chillers in good shape. Depending on the installation, it may be necessary to do more things and do upkeep more often.

Maintenance is important for vapor compression chillers to work well, but it is essential for absorption chillers to work. People have come to think that absorption chillers are unstable and break down often. Most of the time, issues with how the chillers work can be traced back to not doing enough maintenance. Keeping the right pressure in the shell side of the absorber and stopping corrosion in the chiller are two important maintenance tasks.

Check and maintenance schedule for absorption chillers

Activity	Frequency
Check chiller log	Daily
Check general operating conditions	Daily
Check for irregular noise and vibrations	Daily
Inspect for water leaks	Daily
Inspect solution pump motor	Daily
Inspect purge unit operation	Daily
Log purge unit counter reading	Weekly
Sample condenser water	Weekly
Inspect water treatment system	Weekly
Inspect valves for leaks	Weekly
Check filters and strainers	Weekly
Check pH of chilled water and condenser water	Weekly
Sample lithium bromide for testing	Weekly
Test purge unit operation	Yearly
Change purge unit pump oil	Yearly
Calibrate controls	Yearly
Test safeties	Yearly
Chilled water low temperature	Yearly
Chilled water flow	Yearly
Condenser water flow	Yearly
Refrigerant low/high pressure	Yearly
Inspect all wiring, starters and disconnects	Yearly
Test all indicator lights	Yearly
Inspect chiller tubes for scaling and fouling	Yearly
Inspect case for rust	Yearly
Eddy current test tubes	Yearly

Maintaining vacuum

In an absorption chiller, the vacuum is lost because of two things: leaks and the formation of hydrogen. For the refrigerant, which is usually water, to vaporize at low saturation temperatures, there must be a vacuum. If there is a lack of vacuum, the absorber's capacity and how well it works are both lowered. If there are any leaks in the system while the absorber is under pressure, air will get into the system. Air leaks not only reduce the system's capacity and efficiency, but they also let oxygen into the system. Most systems use lithium bromide as an absorbent. It is a salt that becomes very corrosive when it comes in contact with air. If you don't fix vacuum leaks, they will quickly eat away at the steel of the chiller.

When the lithium bromide reacts with the steel surfaces of the chiller, hydrogen gas is made spontaneously. Hydrogen is a gas that doesn't condense, and if it isn't taken out of the system, it will lower its capacity and efficiency.

A purge unit is the best way to control the amount of noncondensable gases in the absorption system. The purge unit, which is similar to the ones used in vapor compression chillers, collects and removes non-condensables from the absorption system. This helps to keep the chiller's capacity and lower the rate of internal corrosion. Crystallization is also less likely to happen because of the purge unit. Lithium bromide crystallizes when it starts to change from a liquid to a solid. When this happens, it forms a crystalline slurry that clogs chiller lines, orifices, pumps, and other places. Crystallization doesn't usually hurt the chiller, but it does stop it from working temporarily. It can be fixed by heating the places where the plugs are so that the lithium bromide can turn back into a liquid.

The working of the purge unit should always be watched. Increasing run times are a sign that the system is leaking and will need to be tested and fixed during the next annual check.

How to Stop Corrosion

To stop internal corrosion, it is also important to remove air from the refrigerant and keep the chemical properties of the lithium bromide within the suggested ranges. To keep the lithium bromide from corroding on the inside, two upkeep tasks are needed: adding a corrosion inhibitor and testing it regularly.

For the lithium bromide to have less of an effect on the steel inside of the chiller, it is important to use a corrosion inhibitor. When used correctly and with a good purge unit, it can slow the rate of internal corrosion to a level that is acceptable.

Lithium bromide needs to be tested often to keep the right pH of the absorbent and keep the chiller system from breaking down or not working as well as it should. the game

Rule of thumb: At least once a month, a sample of the material should be taken and sent to a lab for testing. As with other samples, it's important to keep an eye on the data from the study over time to look for slow trends.

HOW CHILLERS WORK FOR MANAGING ENERGY

In addition to repair tasks that can be done to improve how well a chiller works, operational practices can also be put in place to reduce the amount of energy a chiller uses. As long as the chiller system has the right controls, the operational practices we've talked about here can be put into place with low initial costs, or they may require a small investment in control system changes. Even if changes need to be made, the cost of those changes is so small compared to the money they save that the payback time for those chiller changes can be measured in months.

How to Distribute Chiller Load

This operational practice is for places that have at least two chillers joined in parallel as part of a central chiller plant. In these places, it's common to have more than one chiller running at the same time, with the cooling load spread out fairly among them. Even when the load is low enough that one chiller could handle it, operators keep two going to keep the system's reserve capacity and to make sure that service wouldn't stop if one of the chillers stopped working.

Keeping two chillers running at part load when one chiller could handle the whole load is a waste of energy. As the load on a chiller goes down, its efficiency goes down. For example, a centrifugal chiller that is only running at 50% of its full-load capacity usually uses 60–65% of the energy it would use at full-load. Running two chillers at the same time also adds wear and maintenance needs as the chillers run longer. Even though it helps protect against the failure of a single chiller, the cost increases more than make up for the benefit in all but the most important cases.

In its simplest form, chiller load distribution is the process of starting and stopping chillers to better match on-line chiller capacity with cooling loads. Operators watch how much work the chiller system has to do and start or stop more chillers as needed. The most efficient chiller takes care of the base load for the building. When the load goes up, more chillers are brought online, starting with the idle chiller with the best efficiency. When the load of the building goes down, chillers are turned off, starting with the least efficient one.

In more complicated situations, loads are spread out among several chillers that are all running at the same time. During low load periods, only the most efficient chiller is used. As the load goes up, the next-best chiller is brought online. The most efficient chiller keeps running at full capacity while the load is added to the next most efficient chiller in small amounts. If the load goes down, the increase is taken away from the chiller with the lower efficiency.

Implementing chiller load distribution is mostly about following the right steps. The load assignments must be set up in the chiller control systems, but little or no extra hardware is needed.

Cooling water reset

For years, the normal operating procedure for chiller condenser water temperature has been to keep the temperature of the cooling tower water return at 28°C, no matter how much work the chiller is doing or how hot it is outside. To keep the water at this temperature, the tower fans are turned on and off and the tower escape valves are opened. Most people do this because they think that the chiller works best when the condenser water temperature stays the same and that turning off the cooling tower fans will save energy.

In effect, energy will be saved by lowering the temperature of the cooling tower return water.

Rule of thumb: For every 5.6°C drop in the temperature of the condenser water provided to the chiller, the compressor will use about 15% less energy. With chillers and cooling towers sized for the peak load, systems usually spend more than 95% of the time running at lower loads and situations where condenser water temperatures can be lowered.

All chillers can work even when the water temperature in the condenser is low. How low the temperatures can go varies on the model of the chiller. Manufacturers list the recommended operating ranges for their units. At these lower temperatures, thermal stresses in the heat-exchanger of the chiller will be higher. However, as long as the temperatures stay within the range suggested by the manufacturer, these stresses won't hurt the chiller. In the same way, the rate of scaling in the heat-exchanger of the chiller goes up a little bit, but this can be stopped with good water treatment or tube brushing. Absorption chillers can also be used when the water temperature in the condenser is lower. Even though these chillers are sensitive to condenser water temperatures and will salt up if they are not properly controlled, salting is not a problem as long as they are used within the temperature range suggested by the manufacturer.

To fix the condenser water temperature, the control system for the chiller and cooling tower will need to be changed. The changes are small, and the money spent on them will usually be paid back in less than one cooling season.

Chilled water reset

As with condenser water, the normal operating procedure for chiller cooling water temperature has been to keep the supply water temperature at 6 to 8°C constant, no matter how much work the chiller is doing. In real life, the supply water temperature needed to cool and dehumidify a building depends on the cooling load and the ability of the system. When the system isn't at peak loads, it's possible to lower the temperature of the chilled water source and still meet the load requirements. Increasing the temperature of the chilled water supply can save a lot of energy. For every degree that the temperature goes up, the energy needed to run the compressor goes down by about 1.5 to 2%. If the system is running below its maximum design load most of the time, increasing the temperature of the chilled water supply can save a lot of energy. No changes need to be made to the chiller in order to change the temperature of the chilled water. Each day, the supply water temperature can be set based on how load is expected to be done on the system. But raising the temperature of the chilled water supply does make it harder for the system to control the humidity in the area. Conditions in space will need to be watched in order to save as much money as possible while keeping temperatures and humidity levels under control. Feedback from those conditions then can be used to automatically reset chilled water supply temperatures. Rule of Thumb: Typical payback for such a system is less than one season.

Indirect Free Cooling

It is possible to get a limited amount of "free" cooling from a chiller system under certain circumstances. In this method of operation, the cooling tower and chilled water systems work normally, but the chiller is not turned on. Instead, the chiller's refrigerant movement valves are opened to bring the pressure in the evaporator and condenser to the same level. Since the condenser is cooler than the evaporator, refrigerant condenses in the condenser and moves to the evaporator, and evaporates. So, the heat moves from the chilled water system to the cooling water system, where the cooling tower gets rid of it. In this state of operation, the system usually produces 10 percent of the chiller's full-load cooling capacity.

A method called indirect free cooling makes chilled water that is about 5.6°C warmer than the water that comes from the cooling tower to the chiller. The systems work best in places where the winter cooling load is less than 10 percent of the chiller's peak capacity and the water temperature in the cooling tower can be kept between 5-8°C. To set up indirect free cooling, only small changes on the chiller are needed.

NOTE: We have adapted relevant parts from Mr. Piper's industry standard textbook Chapter 6, converted imperial to metric and simplified the wordings making it an easy read for anyone with basic or moderate command of English.

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